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Translating Exercise Testing into Athletic Performance

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Overview: Terms and Concepts

- Measures of Performance
- Rationale for Measures
- Aerobic vs. Anaerobic Power and Training
- Application of Performance Measures
- Cases to Discuss

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Performance Measures

- Aerobic power
- Anaerobic power
- Lactate Threshold (LT)
- Maximal Lactate at Steady State (MLSS)
- Ventilatory Thresholds (VT)
- Heart Rate Threshold (HRT)
- Economy
- Functional Movement Score

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Physical Abilities Measures

Physical Ability Constructs	Common Indicators
• General Strength ➔	Isometric, isoinertial, and isokinetic strength tests;
• Anaerobic Power ➔	Wingate tests; Horizontal & Vertical Jumps; Sprints
• Muscle Endurance ➔	Sit-ups; push-ups; pull-ups; repetitive weight lifts
• Aerobic Capacity ➔	Maximal oxygen uptake; run tests

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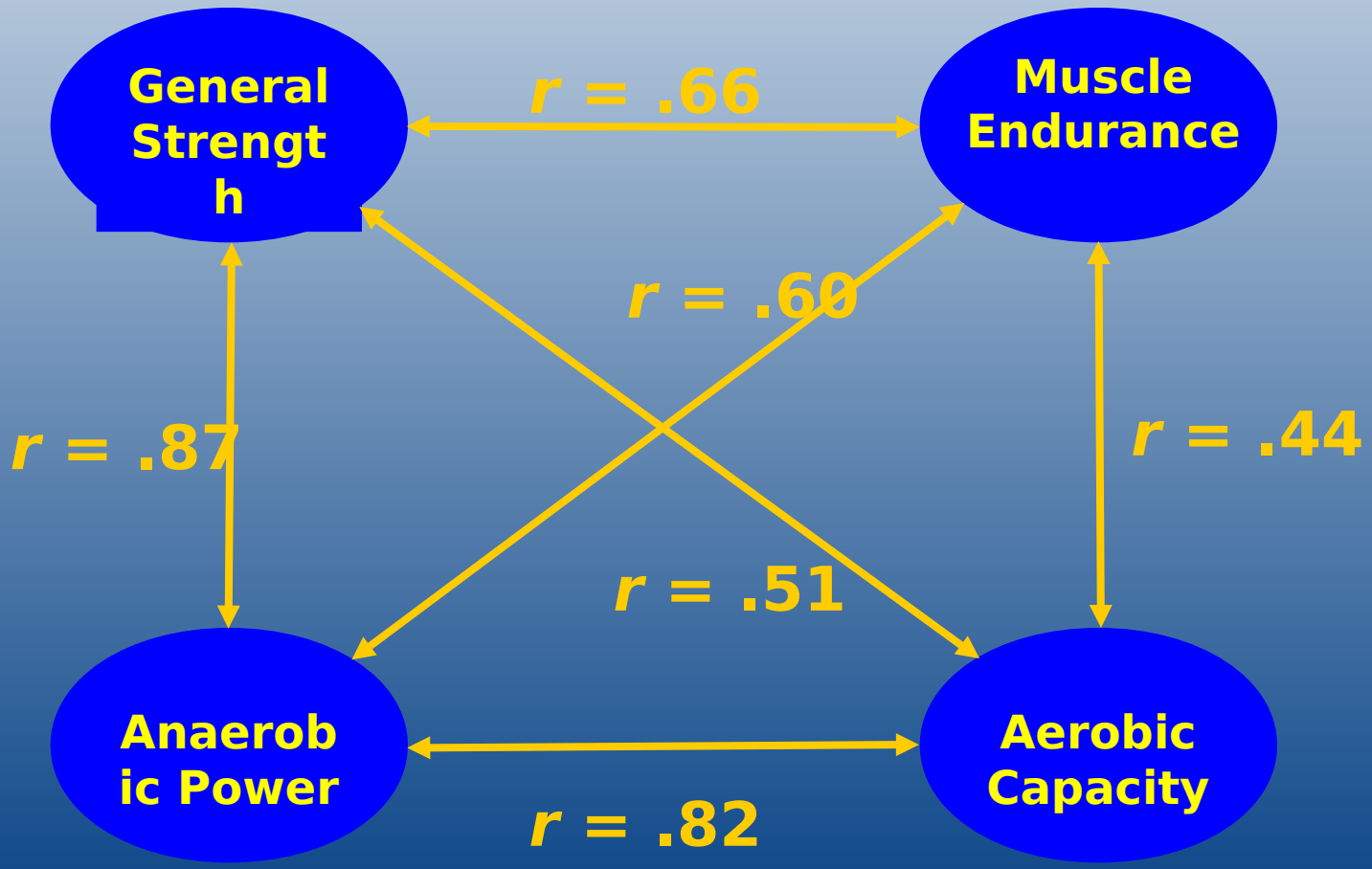
Correlations Among Physical Abilities



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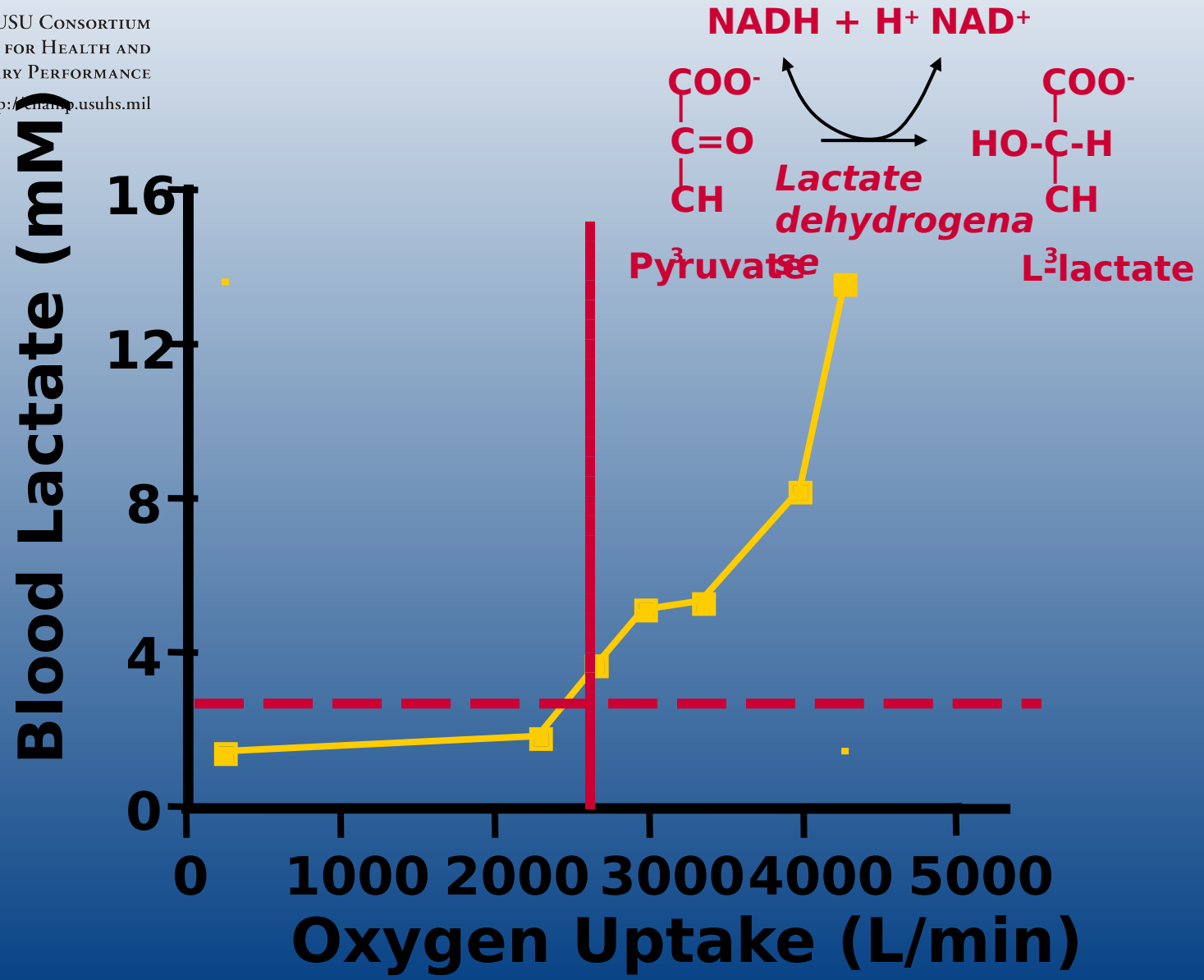
Lactate Threshold



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What is the Lactate Threshold (LT)?

- La- production exceeds removal in blood
  - La- rises in a non-linear fashion
  - Rest [La-] → 1 mM blood (max 12-20 mM)
- LT represents first break-point on the lactate intensity curve:
  - ↑ in glycogenolysis and glycolytic metabolism
  - ↑ recruitment of fast-twitch motor units
  - exceeding mitochondrial capacity for pyruvate
    - pyruvate converted to lactate to regenerate NAD^+ so glycolysis can continue
  - ↓ redox potential (NAD^+/NADH)

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Other LT Terminology

- **Anaerobic threshold (no longer used)**
  - **First used in 1964**
  - **Based on association of ↑ blood La- with hypoxia**
- **Maximal lactate at steady state (MLSS) or Onset of blood lactate accumulation (OBLA)**
  - **Upper limit of blood lactate that results in a lactate steady state during prolonged exercise**
  - **Can vary between 3 and 8 mmol/L**
  - **Usually ~ 4 mmol/L**

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Formation of Lactate is Critical to Cellular Function

- Does not cause acidosis related to fatigue
  - pH in body too high for Lactic Acid to be formed
- Assists in regenerating NAD+ (oxidizing power)
  - No NAD+, no glycolysis, no ATP
- Removes H+ when it leaves cell: proton consumer
  - Helps maintain pH in muscle
- Substrate for glucose/glycogen

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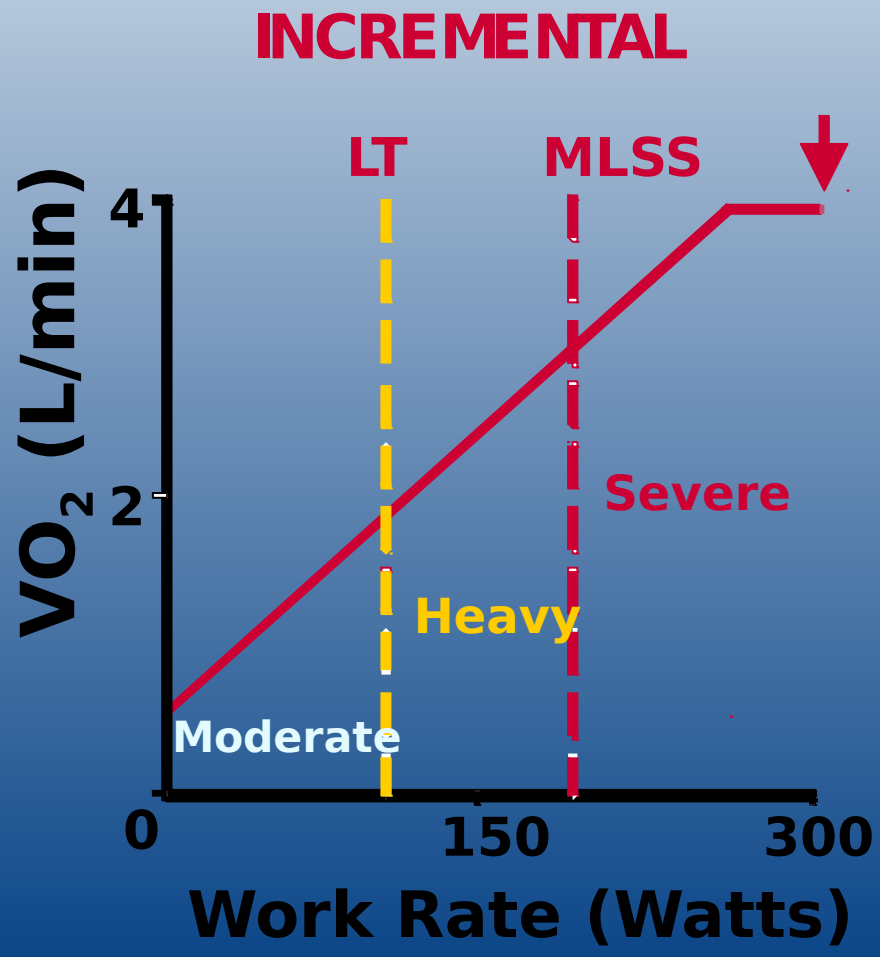
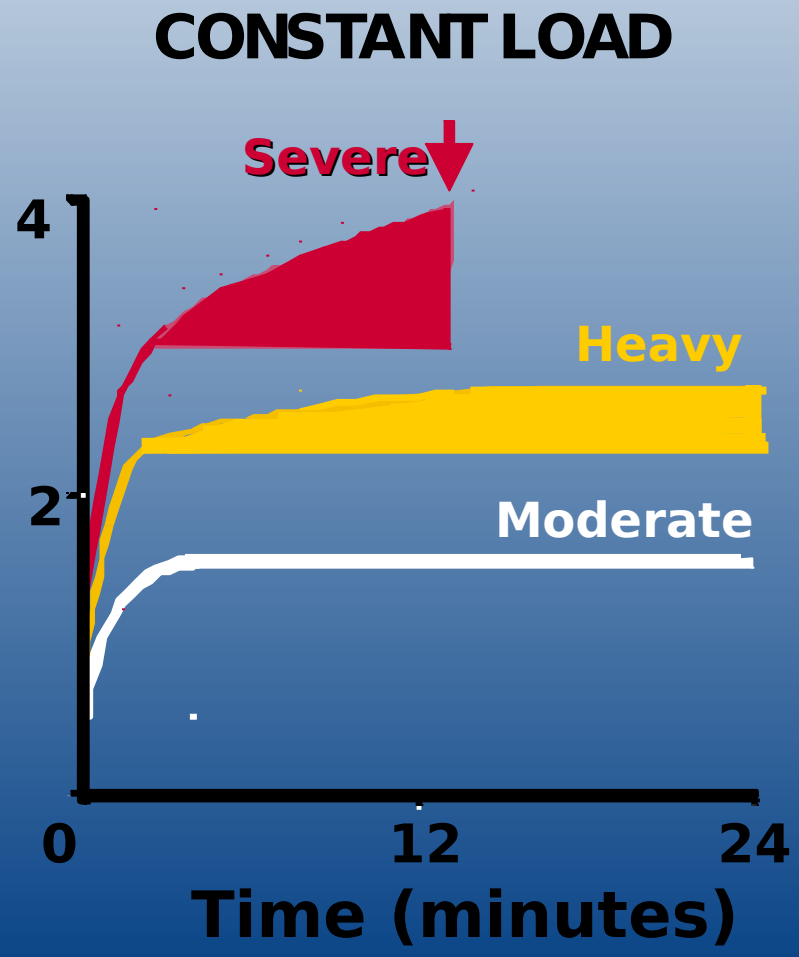
Oxygen Uptake and Exercise Domains





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Ventilatory Thresholds

- **Minute ventilation-O_2 uptake (VE-VO_2) relation during incremental exercise has 2 inflection points:**
  - **Ventilatory threshold (VT): point of a non-linear increase in VE with respect to VO_2**
  - **Respiratory compensation point (RCP): onset of hyperventilation (respiratory compensation) during incremental exercise – a steeper increase in VE vs VO_2 than VT**

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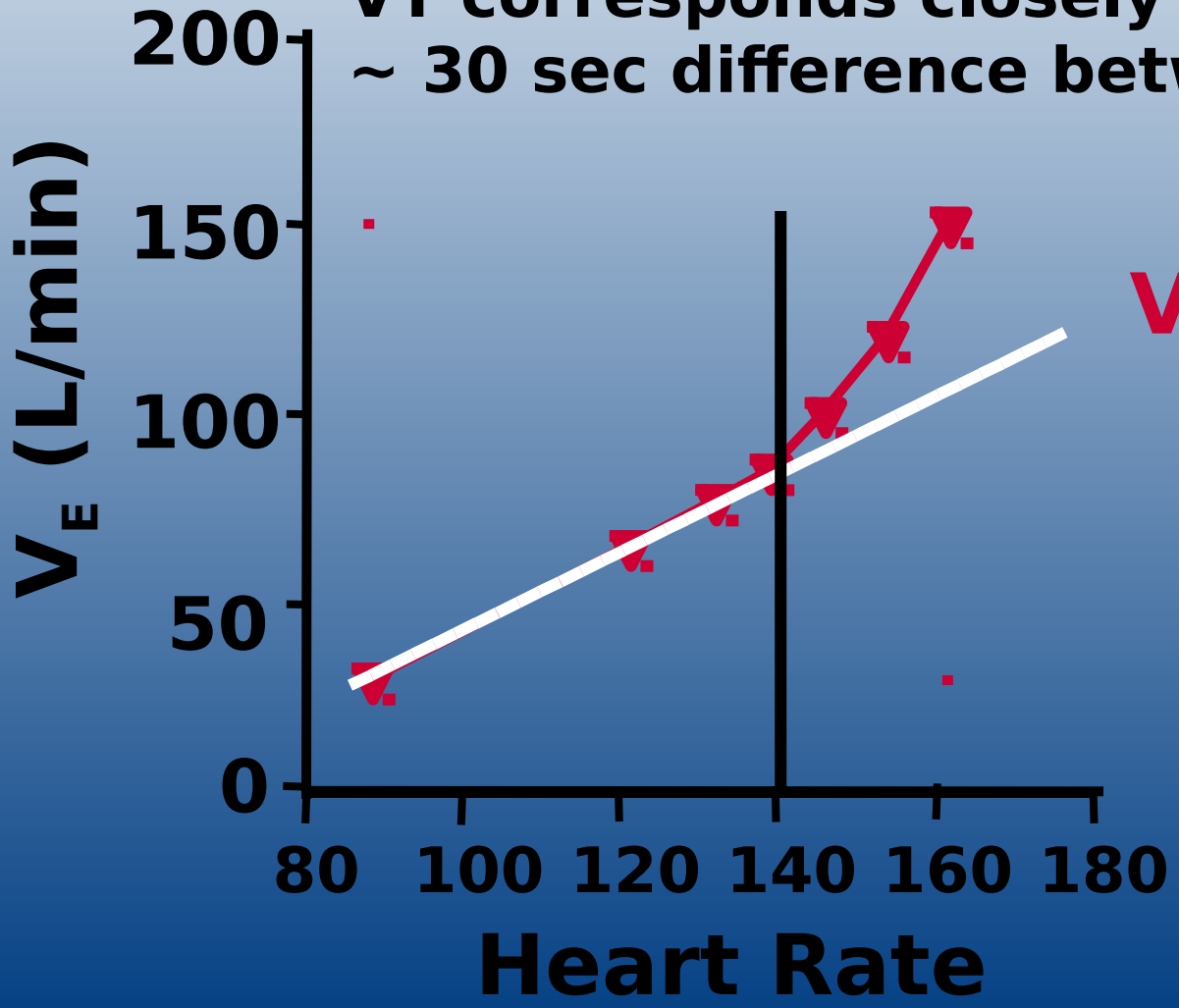
Ventilatory Threshold

VT corresponds closely with LT (r = .9

~ 30 sec difference between LT and V



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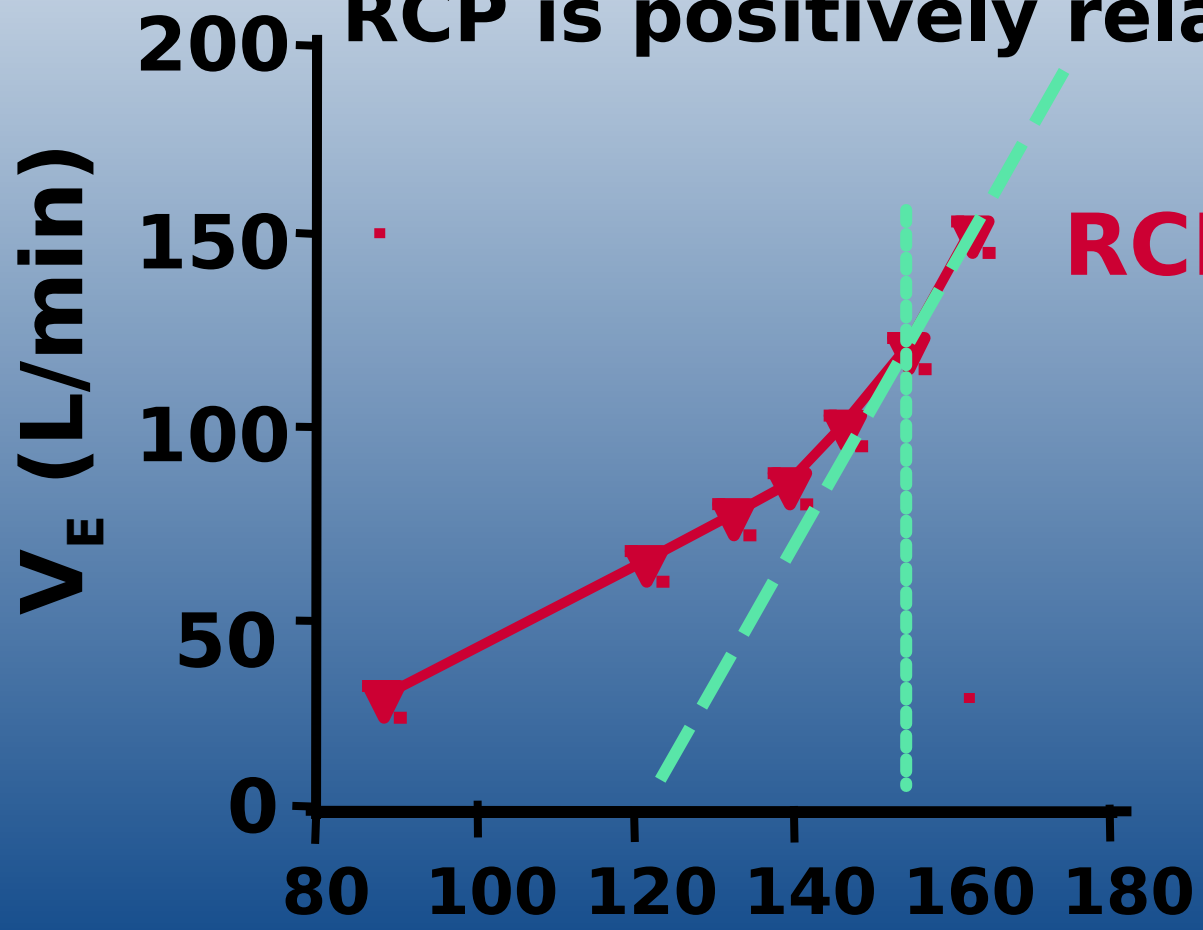
Respiratory Compensation Point

RCP is positively related to VO_{2m}



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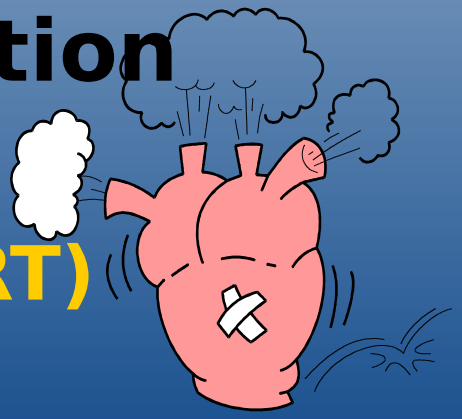
Heart Rate Threshold

- **HR doesn't increase linearly as a function of VO_2 in all people**
  - **can lead to errors in predicting VO_2max**
- **Point where HR-VO_2 relation deviates from linearity:**
  - **Heart Rate Threshold (HRT)**



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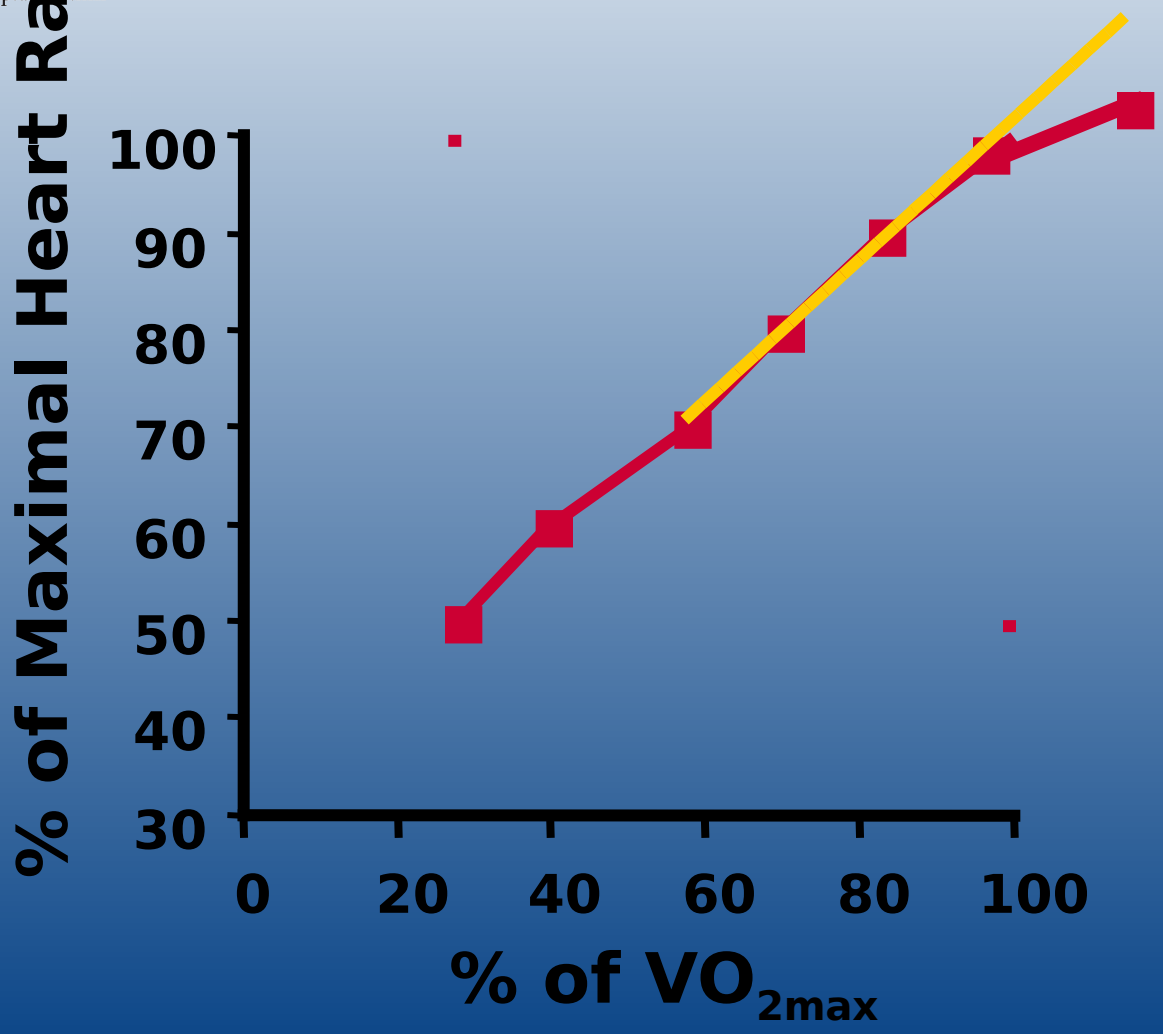
Heart Rate and VO_{2max}



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Economy

- **Economy: energy cost of exercise, "economy of movement", rate of energy expenditure during running**
  - **↑ by interval, plyometric, explosive strength (low load and maximal velocity), and high intensity interval training**
- **Measure VO_2 at 3 speeds between 6 and 12 mph**

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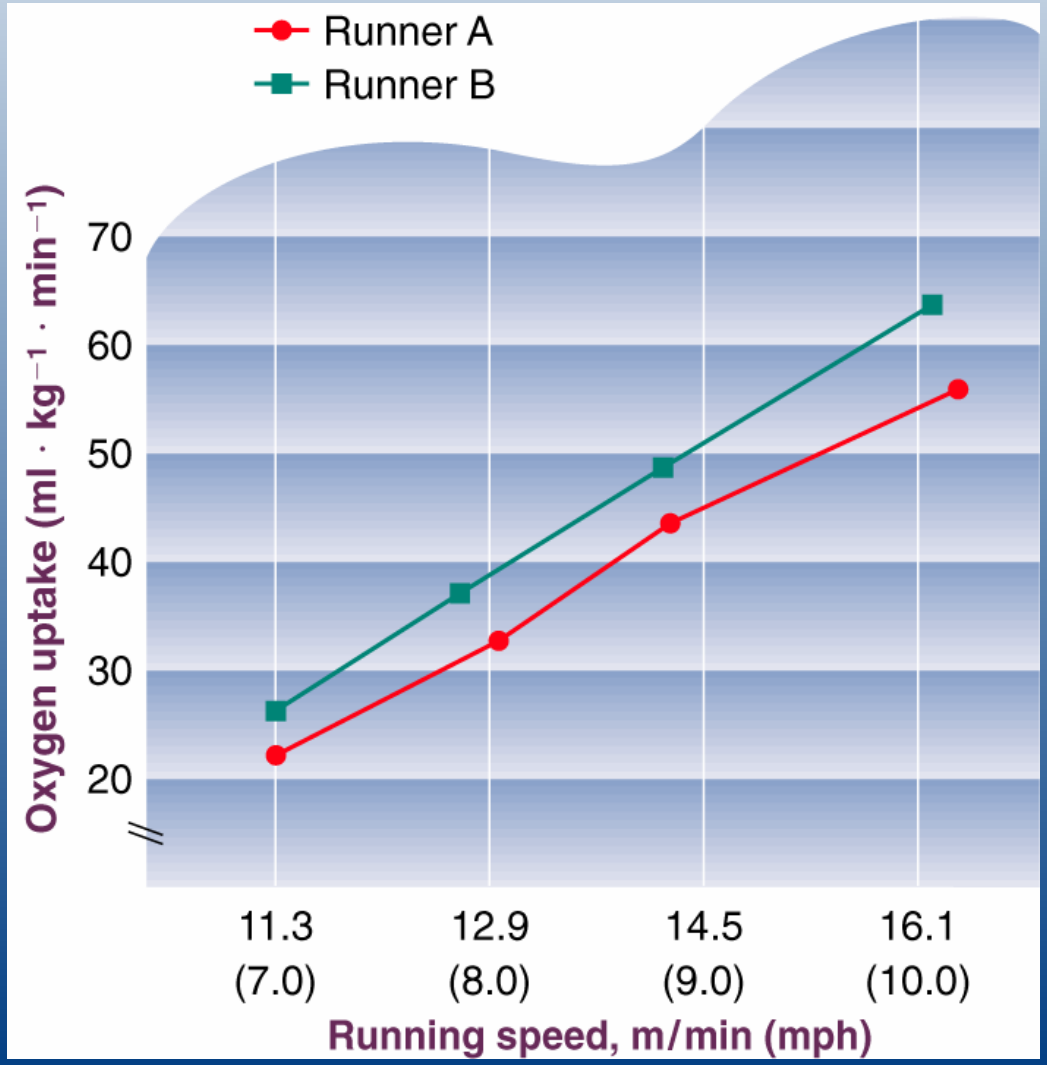
Economy of Two Runners



- **Cycling:**
  - **Physiology**
  - **Seat height**
  - **Pedal cadence**
  - **Shoes**
  - **Wind resistance**
- **Running:**
  - **Physiology**
  - **Stride length**
  - **Shoes**
  - **Wind resistance**

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Velocity at Maximal Aerobic Power or vVO_{2max}

- Running speed which elicits VO_{2max}
- Used by coaches to set training velocity.
- Different methodologies used to establish:
  - Extrapolation from treadmill test
  - Derived from track runs
- Higher in endurance runners than sprinters.
- Improved by endurance training
- A good indicator of endurance performance in middle- and long-distance running events

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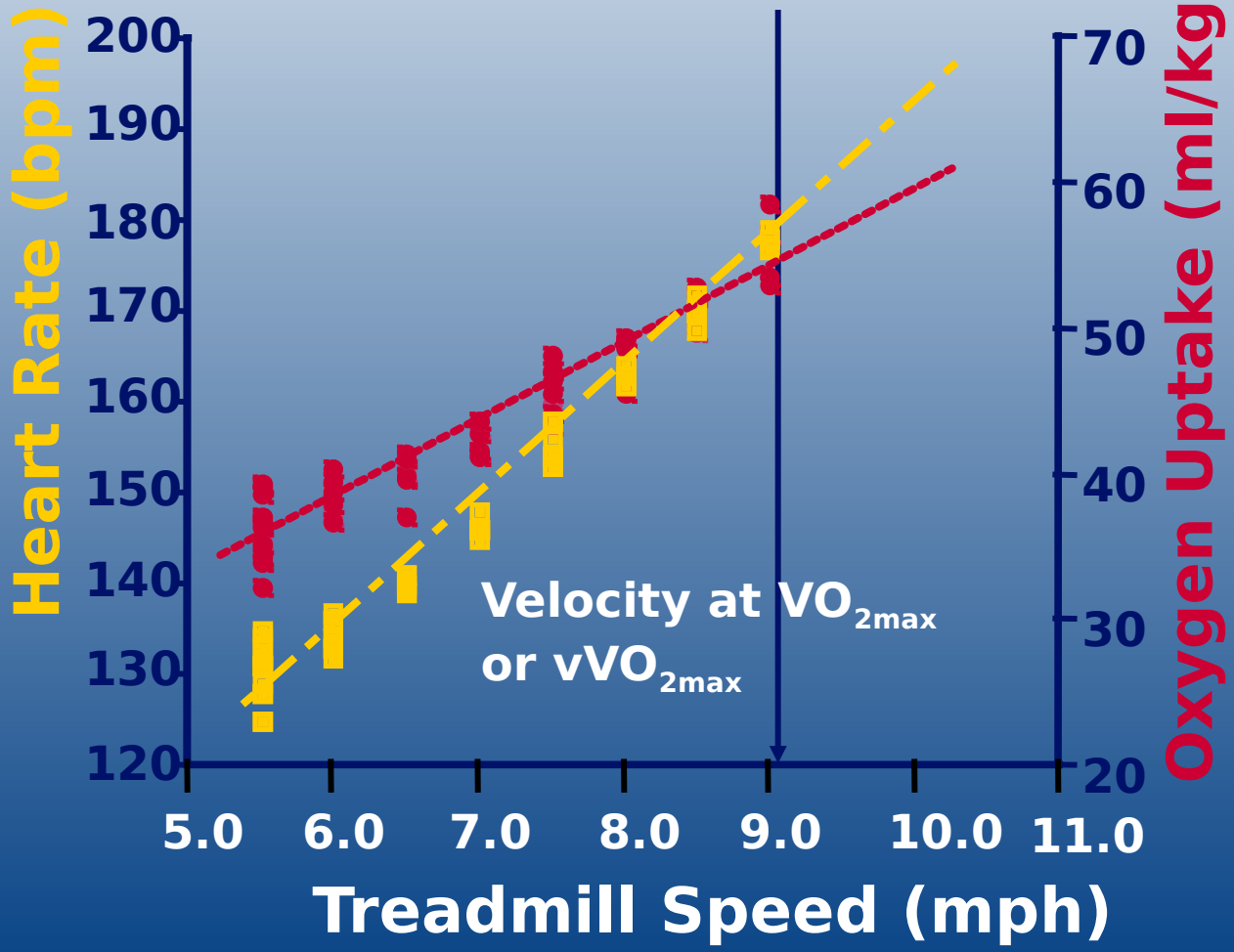
Velocity at Maximal Heart Rate and Oxygen Uptake



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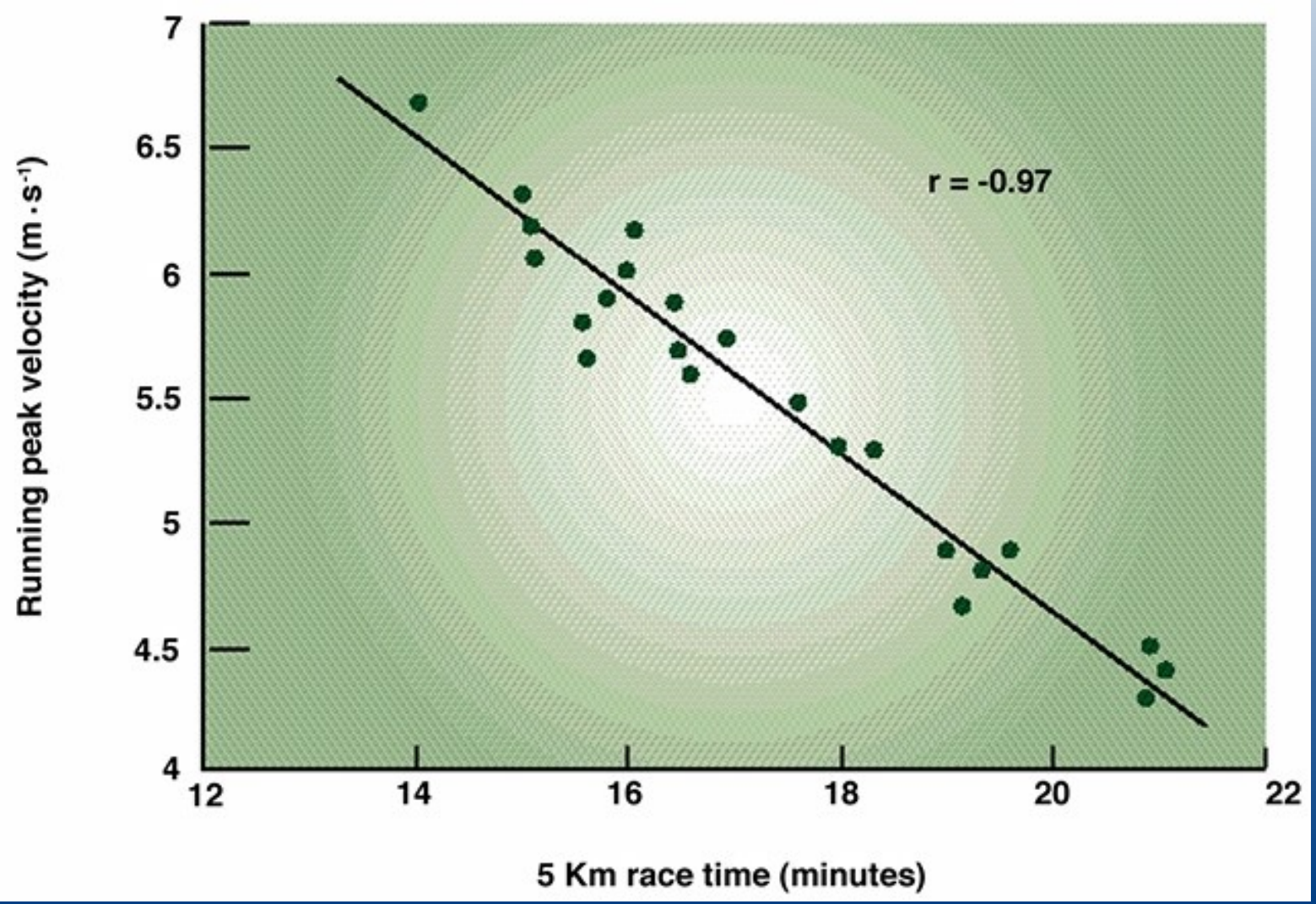
Predicting Performance From Peak Running Velocity



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Training to Improve Performance

- **Goals:**
  - ↑ VO_{2max}
  - Shift LT and MLSS to right
  - ↑ Anaerobic power/capacity
  - ↑ Economy of movement
- **Training methods**
  - Interval training
  - High-intensity, continuous exercise
  - Sprints/Accelerations/Speed Play (Fartlek)
  - Hill tempos
  - Long, slow distance
  - Strength training

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Types of Exercise Performance Tests

- VO_{2max} for aerobic power and capacity
- Wingate and Running tests for anaerobic power, capacity, and fatigue index
- Submaximal cycle/running tests - are more sensitive to training and yield valuable information regarding the training status.
- Functional Movement Screening

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Key Training and Performance Principles

- Overload
- Progression
- FITT: Frequency, Intensity, Time, Type
- Reversibility
- Specificity
- Individualism
- Adaptation
- Periodization

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Guidelines for Interval Training

% of Max Anaerobic Power	Energy System	Interval Time	Work to Rest Ratio
90-100	CP	5-10 s	1:12 to 1:20
75-90	CP-LA	15-30 s	1:3 to 1:5
30-75	LA-Aer	1-3 m	1:3 to 1:4
20-35	Aerobic	> 3 m	1:1 to 1:3

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Long, Slow Distance

- **Low-intensity exercise**
  - **57% VO_{2max} or 70% HR_{max}**
- **Duration > than expecte in competition**
- **Based on idea that train improvements are based volume of training**

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High-Intensity, Continuous Exercise

- **May be best method for increasing VO_{2max} LT, MLSS, and economy**
- **High-intensity exercise**
  - **Repeated exercise bouts (30 sec at intensity ~80 - 110% VO_{2max} or 80-100% HR_{max}) separated by short (30-60 sec), light activity recovery periods**
  - **Slightly above MLSS**
  - **Duration of 25-50 min**
  - **Depends on individual fitness level**
  - **VO_{2max} more likely to be reached when work intervals are intense and rest intervals short.**

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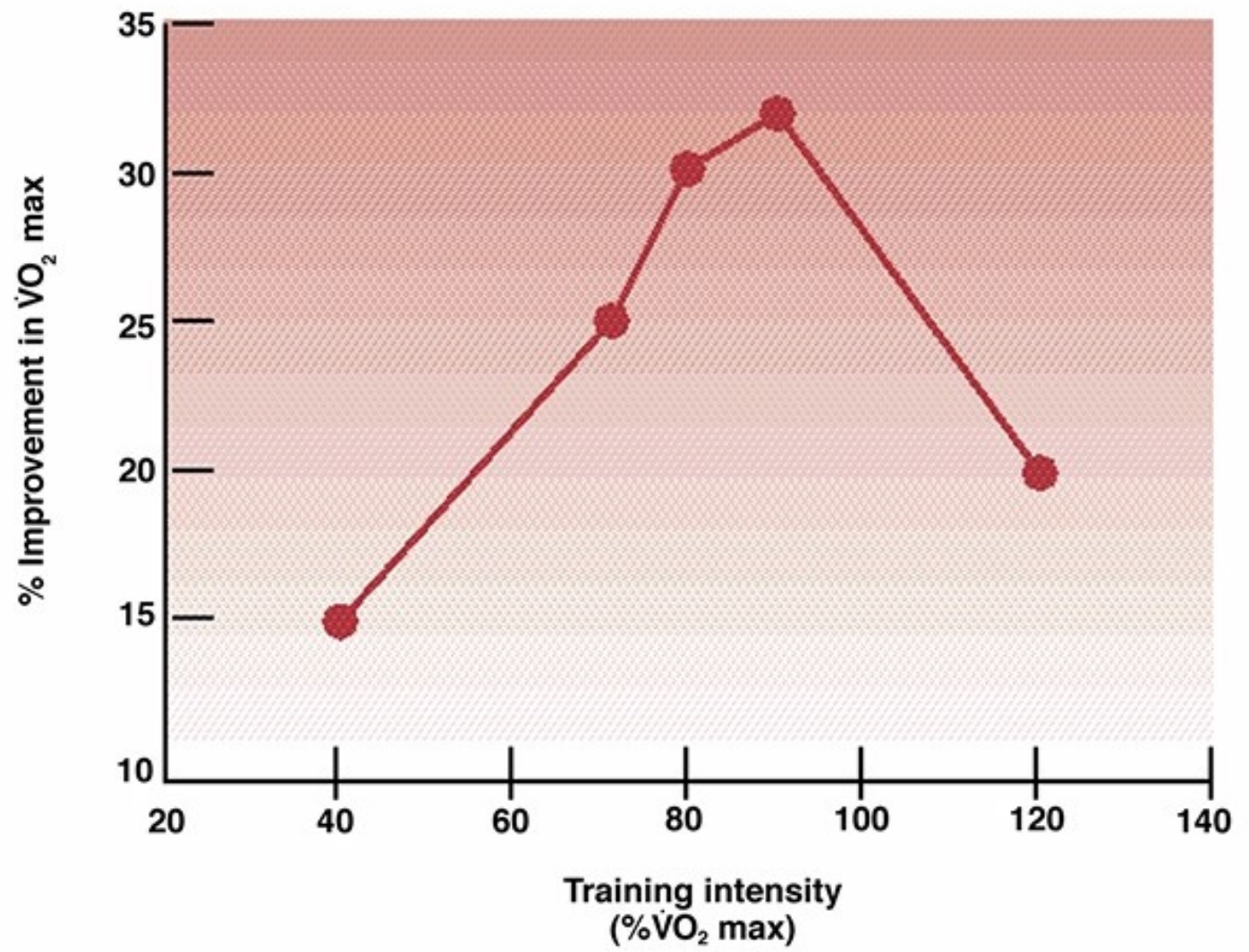
Training Intensity and Improvement in VO_{2max}



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Anaerobic Power and Capacity

- Depends on ATP-PC energy reserves and maximal rate at which energy can be produced by ATP-PCR system.
- Maximal effort
- Cyclists and speed skaters highest.

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Anaerobic Power Tests

- Margaria-Kalamen Power Stair Test
- Standing broad jump
- Vertical jump
- 35 m (40 yd) sprints
- Wingate Test

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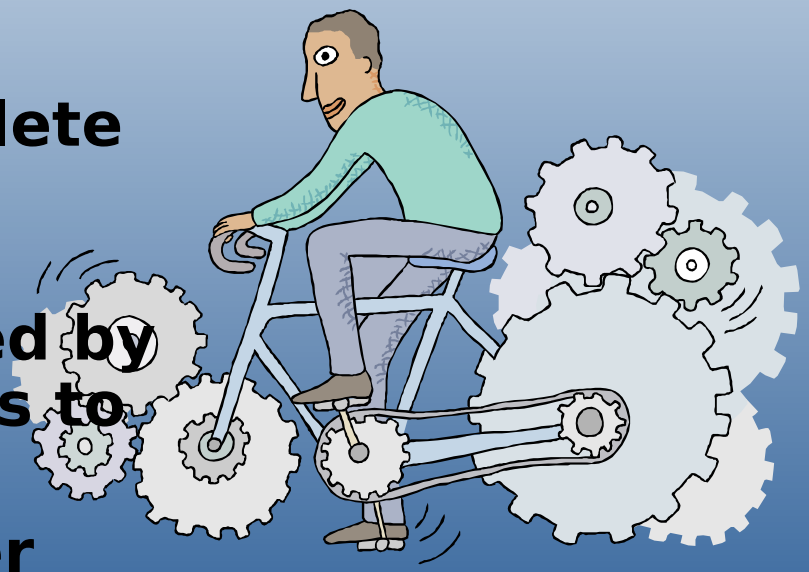
Wingate Test for Anaerobic Power

- **Mechanically-braked bicycle ergometer.**
- **After 10 min warm up, athlete begins pedaling as fast as possible**
- **A fixed resistance is applied by 3 sec and athlete continues to pedal "all out" for 30 sec**
- **Calculate peak/mean power output, anaerobic fatigue, and anaerobic capacity**



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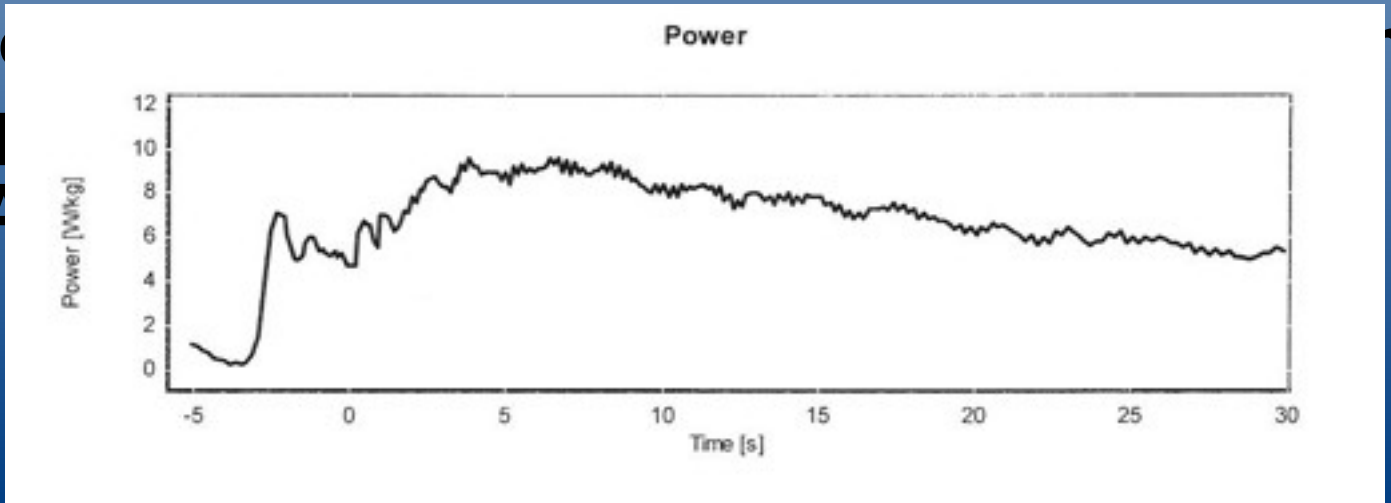
Wingate Test for Anaerobic Power

- **Peak Power (PP): energy generating capacity of immediate energy system (ATP and CP).**
  - **Highest power output during first 5 sec of test**
  - **Relative PP (RPP) = PP/Body mass (kg)**
- **Av… …ng cap… (LA…**



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Wingate Test for Anaerobic Power

- **Anaerobic Fatigue (AF): total capacity to produce ATP via immediate and short term energy systems - % decline in power output.**
  - **AF = (Highest PP - Lowest PP)*100 /Highest PP**
- **Anaerobic Capacity (AC): maximum amount of work that can be produced from immediate energy system.**
  - **AC = Average power X 30 sec or sum of power over 30 sec.**

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Relative Peak and Average Power Among Athletes

Percentile Rank	Male Watts/Kg		Female Watts/Kg	
	PP	AP	PP	AP
90	10.89	8.24	9.02	7.31
80	10.39	8.01	8.83	6.95
70	10.20	7.91	8.53	6.77
60	9.80	7.59	8.14	6.59
50	9.22	7.44	7.65	6.39
40	8.92	7.14	6.96	6.15
30	8.53	7.00	6.86	6.03
20	8.24	6.59	6.57	5.71
10	7.06	5.98	5.98	5.25

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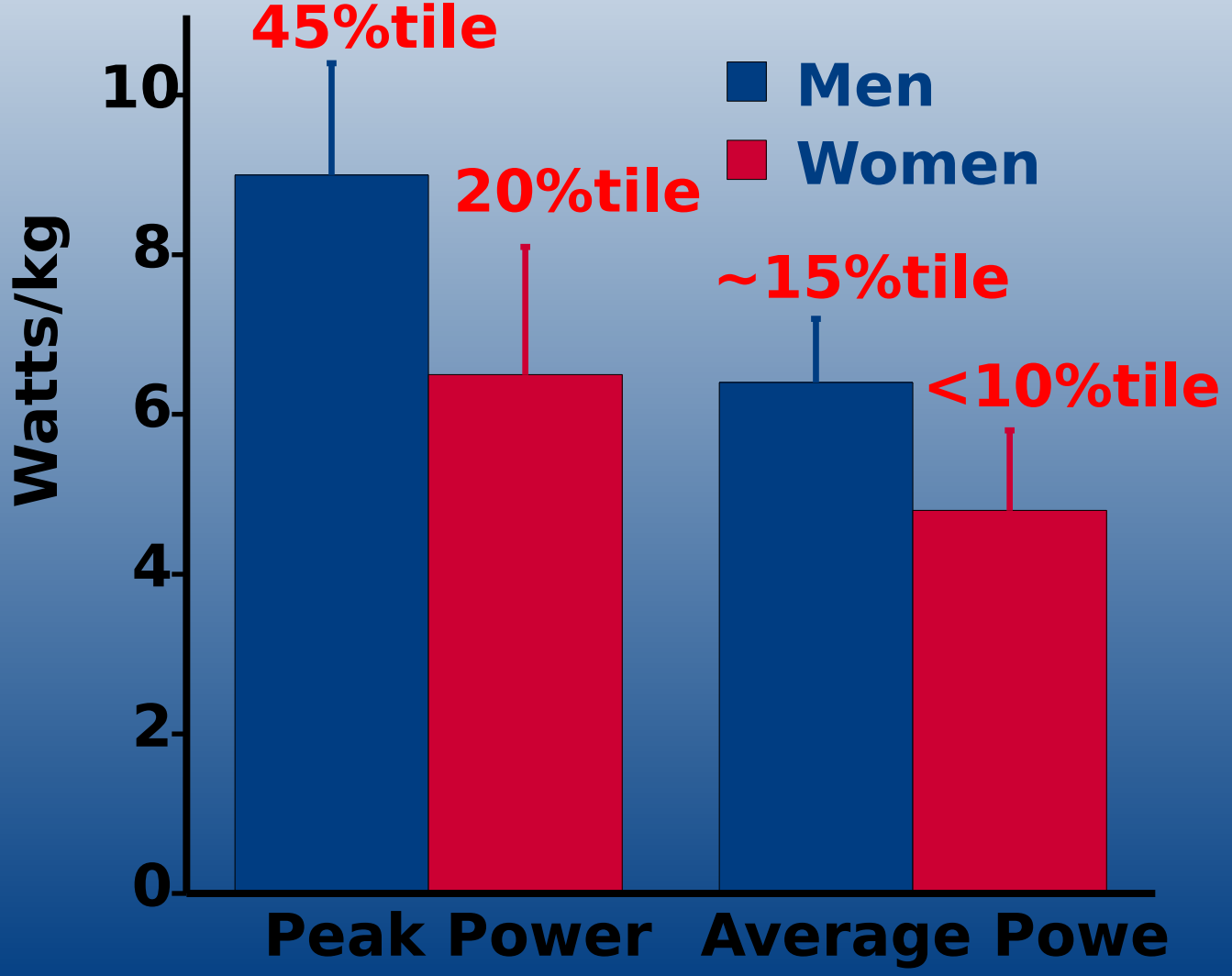
Comparison to HPL Data



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Running-Based Anaerobic Sprint Test

- 400 meter track with straight, 35 m marked section
- Complete six 35 m sprints at max pace (10 sec between sprints for turnaround)
- Record time for each sprint to 0.01 sec
- Calculate Power = (Weight × Distance^2)/Time^3
  - Maximum power: highest value
  - Minimum power: lowest value
  - Average power: sum of all six values ÷ 6
  - Fatigue Index: (Maximum - Minimum power) ÷ Total time for 6 sprints

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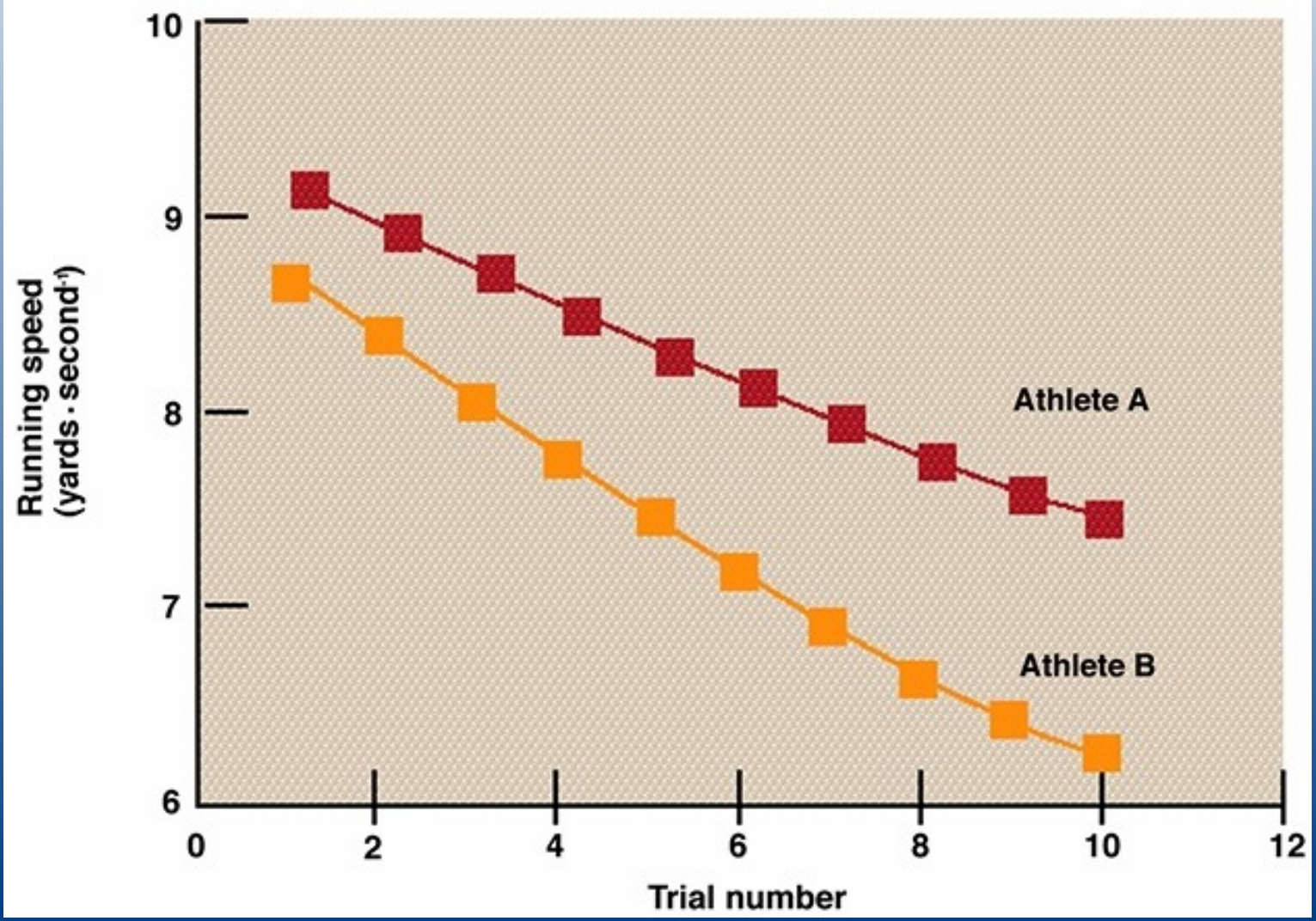
Series of 40-yard Dashes to Quantify Anaerobic Power



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Training for Improved Anaerobic Power

- **ATP-PC system**
  - **Short: 5-10 sec high-intensity work intervals**
  - **30-60 sec rest intervals**
- **Glycolytic system**
  - **Short: 20-60 sec high-intensity work intervals**
  - **1.2-4 min rests intervals**
- **Aerobic System:**
  - **Short: 60-180 sec high-intensity work intervals**
  - **30-1800 sec rest intervals**

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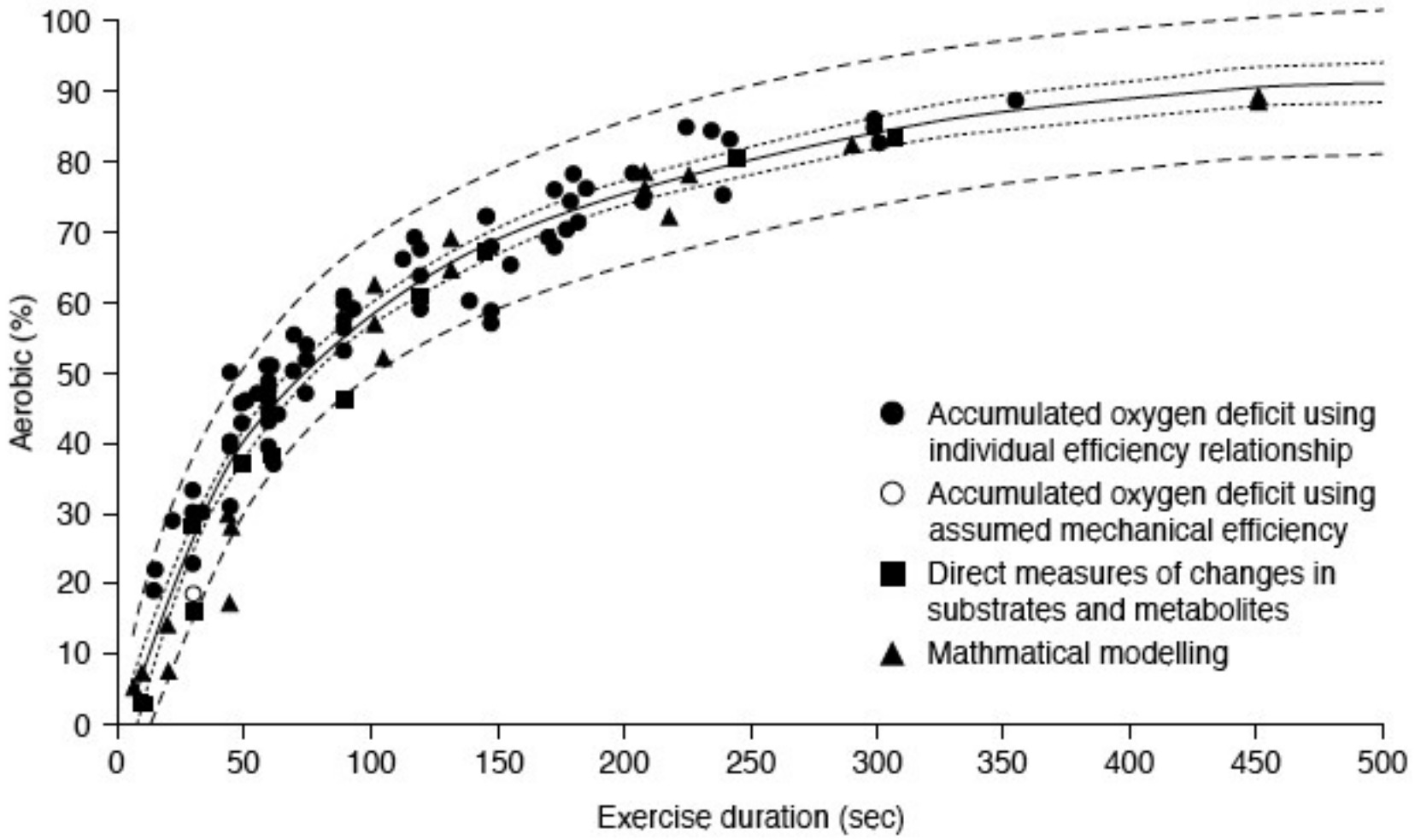
Relative Contribution of Aerobic Energy to Total Energy



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Functional Movement Screening

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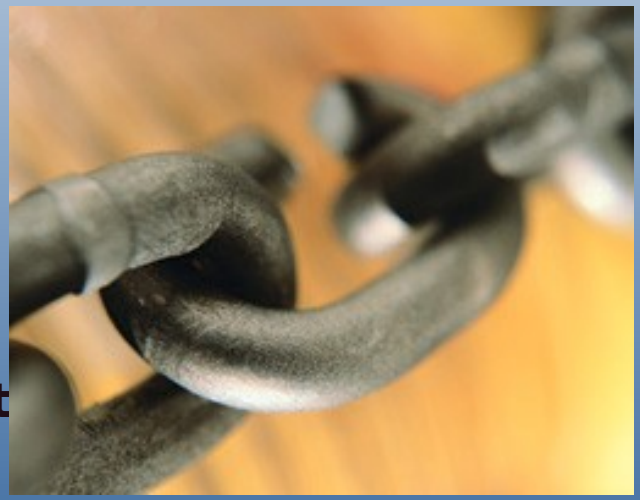
What is FMS?

- **Series of movements designed to screen for:**
  - **Flexibility**
  - **Body movement asymmetry**
  - **Core muscle weakness**
- **Screen to potentially predict injury**
  - **If we can predict it, we can prevent it**
    - **Find the weak link and fix it!**
- **Less Injuries =**
  - **Decreased training losses**
  - **Better warrior retention**
  - **Less use of medical resources and $**



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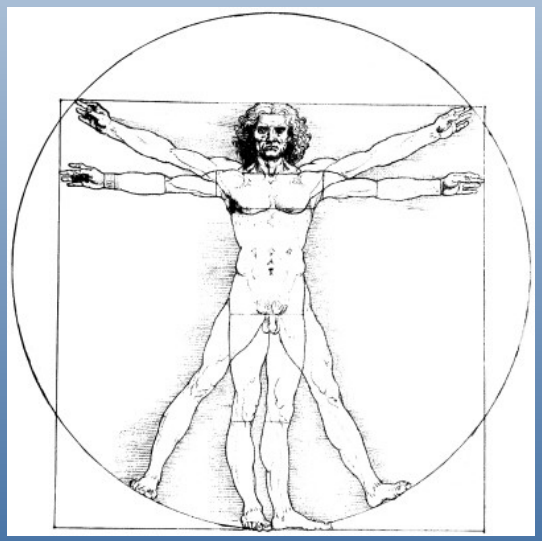
What is FMS?

- 7 fundamental movement patterns
- Graded by trained examiner
- Each movement graded 0 to 3
- Able to target problem movements
- Creates individual functional baseline
- Simple, quick, reproducible
- Deficits can be corrected by physical therapy program



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7 Movements

- Deep Squat
- Hurdle Step
- In-Line Lunge
- Shoulder Mobility
- Straight Leg Raise
- Push-Up
- Rotational Stability

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Functional Movement Screening: A Novel Tool for Injury Risk Stratification of Warfighters

Meghan F. Raleigh, MD; Devin P. McFadden, MD; Patricia A. Deuster, PhD ;Jennifer Davis, MS; Joseph J. Knapik, ScD; Chris G. Pappas, MD; Francis G. O'Connor, MD

Methods

Study Population

- Cohort of 934 Marine officer candidate volunteers during in-processing; informed consent obtained on all subjects.

Results

The mean FMS score was 16.7 ± 1.8 with a range of 6 to 21 (Figure 1). Only 14% had scores ≥ 19 and 0.2% had scores ≤ 10. The most frequent score was 17, with 23% of all volunteers being as

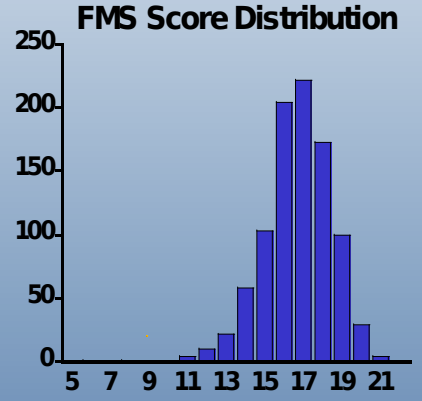

Figure 1. Total FMS score vs. number of candidates with each score. 10.1% of the 934 participants had a score of ≤ 14.

FMS Score	Graduated	Attrition for Injury
≤ 14	85.1	14.9
≥ 15	92.9	7.1

Table 1. Marine officer candidates with overall FMS scores ≤14 and ≥ 15 expressed as a % of those who graduated. Chi-square analysis ignoring "attrition for other than injury" in percentages. Risk ratio (injury attrition/graduated) = 2.08, 95% CI= 1.14-3.82, p<0.02.

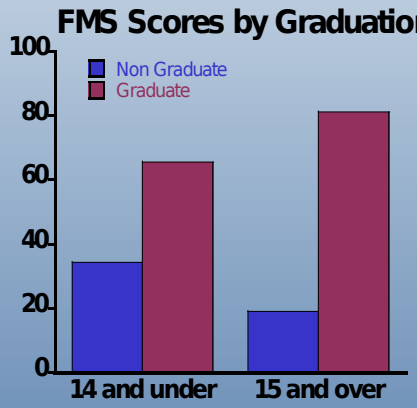

Figure 2. FMS Scores by graduation

Conclusions

Our preliminary analyses demonstrate that FMS can be conducted on a large cohort of military personnel to yield a wide range of scores. Only 10% of participants had a score ≤ 14, and these candidates were twice as likely to not graduate due to injury than those with higher scores.

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Case 1: 37 year old, 84.5 kg, male runner

Wants to ↓10k run time by 40 sec

- VO_{2max} = 60 ml/kg/min
- VT = 50.1 ml/kg/min
- LT = 45.2 ml/kg/min

VT = 83.5% and LT = 75.2% of VO_{2max}

Possible Recommendations:

8-15 30 sec sprints at vVO_{2max}

8 X 400 m repeats at 1 mile pace with 400 m recovery

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Case 2: 27 year old, 120 kg male weightlifter

Wants to ↑ upper body strength

- VO_{2max} = 30.1 ml/kg/min
- VT = 15.1 ml/kg/min
- Peak/Minimal Power = 1,111/306 Watts

VT = 50% of VO_{2max} and AF = 72.5%

Possible Recommendations:

Place on aerobic conditioning program

Walk on a treadmill at 3 mph and 2.5% grade 30 min, 4X/week

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Case 3: 29 year old, 61.5 kg female cyclist

Wants to ↓ 50 k bike time by 15 min

- VO_{2max} = 50 ml/kg/min or ~212 Watts or 3.5 Watts/kg; LT at 2.5 Watts/kg
- Peak Bike Power = 410 Watts or 6.7 Watts/kg

LT = 71.4% of VO_{2max}

Possible Recommendations:

6-10 x 1 mile repeats between LT and ma

3 X 8 min all out with 2 - 4 min recov

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Case 4: 18 yo 50 kg female, cross country runner want to improve 5k time

What tests would you want?

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Case 5: 49 yo 80 kg male wants to improve marathon time

What tests results would you want?

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Summary

- Certain physiologic measures are good indicators of performance
- Many performance tests can be conducted
- Multiple variations of training programs can be devised to improve performance
- All energy systems should be trained.